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A Cost-Benefit Analysis of the EU 20/20/2020 Package

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Abstract: The European Commission did not publish a cost-benefit analysis for its 2020 climate package. This paper fills that gap, comparing the marginal costs and benefits of greenhouse gas emission reduction. The uncertainty about the marginal costs of climate change is large and skewed, and estimates partly reflect ethical choices (e.g., the discount rate). The 2010 carbon price in the ETS can readily be justified by a cost-benefit analysis. Emission reduction is not expensive provided that policy is well-designed, a condition not met by planned EU policy. It is probably twice as expensive as needed, costing one in ten years of economic growth. The EU targets for 2020 are unlikely to meet the benefit-cost test. For a standard discount rate, the benefit-cost ratio is rather poor (1/30). Only a very low discount rate would justify the 20% emission reduction target for 2020.

Key words: European Union; climate policy; cost-benefit analysis

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1. Introduction

The European Union aims to limit its 2020 greenhouse gas emissions to 80% of its 1990 emissions (European Parliament and Council of the European Union 2009a;European Parliament and Council of the European Union 2009c) and to meet 20% of its energy needs by renewables (European Parliament and Council of the European Union 2009b). The European Commission has published an impact assessment (CEC 2008a;CEC 2008b), but not a cost-benefit analysis – an earlier cost-benefit analysis (CEC 2005a;CEC 2005b) covered the eventual target but not the intermediate ones, let alone the details of policy implementation. This paper fills the gap, estimating the costs and the benefits of reducing greenhouse gas emissions by 20% in a decade.[1]

Climate policy is one of the cornerstones of the European Union. It seeks to be a world leader in this area, an ambition which is broadly supported by the public (TNS Opinion and Social 2009). The "climate and energy package" for 2020 implements European climate policy in the medium-term. The Emissions Trading System (ETS) for carbon dioxide will be expanded in scope, the cap will be tightened, and permits will increasingly be auctioned. There are, for the first time, firm targets for greenhouse gas emissions outside the ETS. There are targets for the market share of renewable energy too. These policies will raise the price of energy, slow down economic growth, and reduce welfare. In return, emissions will fall, climate will change less, and the impacts of climate change will be reduced. It is reasonable to ask whether the benefits – i.e., the avoided damages of climate change – outweigh the costs. Maybe European climate policy is too ambitious, or maybe it is not ambitious enough.

The results of cost-benefit analyses should always be interpreted with care, because estimates of the costs and the benefits of an intervention are never complete and rarely do justice to the complexity of the situation (Pearce 1976). These problems are

[1] Note that total emissions in 2008 were very close to those in 1990. Note also that EU emissions were reasonably stable because emissions are increasingly outsources to other countries, particularly in Asia (Davis and Caldeira 2010;Helm et al. 2007;Peters 2008;Peters and Hertwich 2008a;Peters and Hertwich 2008b;Yunfeng and Laike 2010)

particularly pronounced for evaluations of such problems as climate change, which is global, diffuse, unequal, long-lived, and uncertain (van den Bergh 2004). Nevertheless, cost-benefit analysis is far superior as a guide to good policy than the hand-waving practised by some politicians. The results of this paper should therefore be treated with caution but not dismissed out of hand.

The analysis in this paper is about climate change. The policy package also refers to the benefits of improved energy security, higher employment, and accelerated innovation. I do not attempt to quantify these benefits, or even argue about the likely sign.

In Section 2, I survey the economic impacts of climate change. In Section 3, I study the impacts of greenhouse gas emission reduction. In Section 4, I combine the two in a cost-benefit analysis of the EU 20/20/2020 package. Section 5 concludes.

2. Benefits of climate policy

(Tol 2009b) reviews the total economic impacts of climate change. There are positive and negative impacts of climate change. Positive impacts dominate in the short run (when climate change is largely beyond human control), but negative impacts dominate in the medium and long run. Impact estimates are uncertain, incomplete and controversial but the available evidence suggests that a century of climate change is most likely about as bad as losing one year of economic growth and probably less bad than losing a decade of growth. In the course of decade, the European Union can only have a small effect of climate change. Therefore, estimates of the marginal damage costs are more relevant than estimates of the total damage costs.

The marginal damage cost of carbon dioxide, also known as the "social cost of carbon," is defined as the net present value of the incremental damage due to a small increase in carbon dioxide emissions. For policy purposes, the marginal damage cost (if estimated along the optimal emission trajectory) would be equal to the Pigouvian tax that could be placed on carbon, thus internalizing the externality and restoring the market to the efficient solution.

(Tol 2009b) reports 47 studies with 232 estimates of the social cost of carbon. Table 1 shows some characteristics of a meta-analysis of the published estimates of the social cost of carbon. One key issue in attempting to summarize this work is that just looking at the distribution of the medians or modes of these studies is inadequate, because it does not give a fair sense of the uncertainty surrounding these estimates – it is particularly hard to discern the right tail of the distribution which may dominate the policy analysis (Tol 2003;Tol and Yohe 2007;Weitzman 2009). Because there are many estimates of the social cost of carbon, this can be done reasonably objectively. The idea here is to use one parameter from each published estimate (the mode) and the standard deviation of the entire sample—and then to build up an overall distribution of the estimates and their surrounding uncertainty on this basis using the methodology in (Tol 2008).[2] The results are shown in Table 1.

Table 1 reaffirms that the uncertainty about the social costs of climate change is very large. The mean estimate in these studies is a marginal cost of carbon of €49 per metric tonne of carbon dioxide, but the modal estimate is only €14/tCO_2 – close to the EU ETS price of €15/tCO_2. Of course, this divergence suggests that the mean estimate is driven by some very large estimates—and indeed, the estimated social cost at the 95th percentile is €185/t CO_2 and the estimate at the 99th percentile is €439/t CO_2.

This large divergence is partly explained by the use of different pure rates of time preference in these studies. Table 1 divides up the studies into three subsamples which use the same pure rate of time preference. A higher rate of time preference means that the costs of climate change incurred in the future have a lower present value, and so for example, the mean social cost of carbon for the studies with a 3 percent rate of time preference is €5/ tCO_2, while it is €76/ tCO_2 for studies that choose a zero percent rate of time preference. [3] But these columns also show that even when the same discount rate is used, the variation in estimates is large. Table 1 shows that the estimates for the whole sample are dominated by the estimates based on lower discount rates.

[2] I fitted a Fisher-Tippett distribution to each published estimate using the estimate as the mode and the *sample* standard deviation. The Fisher-Tippett distribution is the only two-parameter, fat-tailed distribution that is defined on the real line. A few published estimates are negative, and given the uncertainties about risk, fat-tailed distributions seem appropriate (Tol 2003;Weitzman 2009). The joint probability density function follows from addition, using weights that reflect the age and quality of the study as well as the importance that the authors attach to the estimate – some estimates are presented as central estimates, others as sensitivity analyses or upper and lower bounds. See http://www.fnu.zmaw.de/Social-cost-of-carbon-meta-analy.6308.0.html

[3] Note that the estimates with a discount rate of zero percent are not much higher than the estimates with a discount rate of 1%. The main reason is that most estimates are (inappropriately) based on a finite time horizon. With an infinite time horizon, the social cost of carbon would still be finite, because fossil fuel reserve are finite and the economy would eventually equilibrate with the new climate, but the effect of the zero discount rate would be more substantial. For the record, there is even one estimate (Hohmeyer and Gaertner 1992) based on a zero consumption discount rate (Davidson 2006;Davidson 2008) and thus a *negative* pure rate of time preference.

Although Table 1 reveals a large estimated uncertainty about the social cost of carbon, there is reason to believe that the actual uncertainty is larger still. First of all, the social cost of carbon derives from the total economic impact estimates – and I argue above that their uncertainty is underestimated too. Second, the estimates only contain those impacts that have been quantified and valued – and I argue below that some of the missing impacts have yet to be assessed because they are so difficult to handle and hence very uncertain. Third, although the number of researchers who published marginal damage cost estimates is larger than the number of researchers who published total impact estimates, it is still a reasonably small and close-knit community who may be subject to group-think, peer pressure and self-censoring.

3. Impacts of emission reduction: A survey

The IPCC[4] periodically surveys the costs of emission abatement (Barker et al. 2007;Hourcade et al. 1996;Hourcade et al. 2001); there are the EMF[5] overview papers (Weyant 1993;Weyant 1998;Weyant 2004;Weyant et al. 2006;Weyant and Hill 1999), and there a few recent meta-analyses as well (Barker et al. 2002;Fischer and Morgenstern 2006;Kuik et al. 2009;Repetto and Austin 1997). There are two equally important messages from this literature. First, a well-designed, gradual policy can substantially reduce emissions at low cost to society. Second, ill-designed policies, or policies that seek to do too much too soon can be orders of magnitude more expensive. While the academic literature has focussed on the former, policy makers have opted for the latter.

The costs of emission reduction increase, and the feasibility of meeting a particular target decreases if:

- different countries, sectors, or emissions face different explicit or implicit carbon prices (Boehringer et al. 2006b;Boehringer et al. 2006a;Boehringer et al. 2008;Manne and Richels 2001;Reilly et al. 2006);
- the carbon prices rises faster or more slowly than the consumption discount rate (Manne and Richels 1998;Manne and Richels 2004;Wigley et al. 1996);
- climate policy is used to further other, non-climate policy goals (Burtraw et al. 2003); and
- climate policy adversely interacts with pre-existing policy distortions (Babiker et al. 2003;Parry and Williams III 1999).

[4] Intergovernmental Panel on Climate Change; http://www.ipcc.ch/
[5] Energy Modeling Forum; http://emf.stanford.edu/

Unfortunately, each of these four conditions is likely to be violated in reality. For instance, only select countries have adopted emissions targets. Energy-intensity sectors that compete on the world market typically face the prospect of lower carbon prices than do other sectors. Climate policy often targets carbon dioxide but omits methane and nitrous oxide. Emission trading systems have a provision for banking permits for future use, but not for borrowing permits from future periods. Climate policy is used to enhance energy security and create jobs. Climate policy is superimposed on energy and transport regulation and taxation.

The costs of emission reduction would also increases if emissions grow faster, if the price of fossil fuels is lower, or if the rate of technological progress in alternative fuels is slower than anticipated. This risk is two-sided. Emissions may grow more slowly, the price of fossil energy may be higher, and the alternative fuels may progress faster than expected.[6]

There are only a handful of studies that estimate the economic impact of the EU emissions and energy targets for 2020 – roughly, the EU strives for a 20% reduction in greenhouse gas emissions and a 20% share of renewables in total energy supply. The European Commission commissioned an impact assessment (Capros and Mantzos 2000), and the Energy Modeling Forum organised an independent review (Bernard and Vielle 2009;Böhringer et al. 2009a;Böhringer et al. 2009b;Kretschmer et al. 2009). To the best of my knowledge, no Member State ordered a separate impact assessment; and no academic (outside the EMF) studied the implications of the policies.

(Capros and Mantzos 2000) report cost estimates for every single country of the European Union. They report results for a large number of scenarios; I here use two, one that is slightly more economically sophisticated than the actual policy and one that is slightly less sophisticated. (Bernard and Vielle 2009;Kretschmer et al. 2009) and (Bernard and Vielle 2009) report estimates for a number of regions of the EU, while (Boeters and Koornneef 2010) and (Böhringer et al. 2009a) report for the EU as a single region. I assume homogeneity within the modelled regions, that is, every Member State within a region has the same impact as the region as a whole. Thus, there are six estimates for each country.

[6] Note that the rate of technological progress is largely beyond the control of policy makers, at least between now and 2020.

Figure 1 shows the average of the five estimates for the welfare loss per country in 2020. Table 2 has all the results. The EU as a whole would lose 1.3% of welfare, with a range of 0.4% to 4.5%. Spain and Italy would be hit hardest with a mean loss of 1.7%. Belgium and the Netherlands would see positive impacts (when average across the five studies) of 0.1% and 0.2%. Note that 4 out of 5 models estimate a negative effect for these countries. (Bernard and Vielle 2009) are the exception, predicting a substantial improvement in the competitive position of these countries. The Netherlands particularly benefits from a lower oil price (the feedstock for its export-oriented chemical industry) and higher (absolute) margins on transport and re-export. For the EU as a whole, however, climate policy is costly. A loss of 1.3% is of course not dramatic, but it is projected to occur over the space of only eight years (2013-2020), so that roughly one in every ten years of growth is lost. I'll discuss below whether this investment is justified.

(Böhringer et al. 2009b) show that the 1.3% loss is at least a factor two higher than it could be. This is because of the EU pays lip service only to cost-efficacy in the regulation of greenhouse gas emissions. Particularly, instead of one price for carbon, there are at least 28 prices: one in the ETS, and at least one per Member State for non-ETS emissions. Furthermore, climate policy is also used to serve other policy targets, particularly on renewables and energy security. Besides, climate policy is placed on top of pre-existing regulations.

Figure 2 shows the price of carbon in 2020. Table 3 shows the detailed results. The price in the EU Emissions Trading System (ETS) is some €32/tCO_2, with a range from €7/tCO_2 to €71/tCO_2. The (unweighted) average price outside the ETS is much higher: €75/tCO_2. The non-ETS carbon price exceeds €32/tCO_2 in four countries: Belgium (€175/tCO_2), UK (€126/tCO_2), France (€120/tCO_2) and the Netherlands (€116/tCO_2). Although some Eastern and Southern European countries have been allocated more non-ETS emission rights than they will likely need, the non-ETS price of carbon is zero in one country (Poland) in one model (Bernard and Vielle 2009) only. This is because there is a restricted trade in non-ETS allowances. The non-ETS market price settles on €42/tCO_2; this creates a scarcity in all countries and scenarios but one.

4. A benefit-cost analysis of EU climate policy for 2020

4.1. Introduction

To a first approximation, a benefit-cost analysis of greenhouse gas emission reduction policy requires that the marginal costs of emission reduction be equal to the marginal benefits of emission reduction. When evaluating climate policy for a single continent over an eight year period, the approximation is in fact fairly accurate.

Note that EU emissions are a small and shrinking fraction of global emissions. Therefore, emission reduction in the EU only, and only between 2013-2020, necessarily has a minimal effect on climate change and its impacts. This argument is irrelevant, however, as it militates against any long-term investment programme. For example, by the same reasoning, it is pointless to teach children how to write the letter “a” as it is useless without the rest of the alphabet, or if no other children would learn how to read and write. Emission reduction by any jurisdiction in any legislative period necessarily has a small effect. That is no reason not to do it. It is a reason, though, to evaluate costs and benefits at the margin.

4.2. Marginal costs and benefits

Section 2 estimates the marginal damage costs of climate change. Section 3 estimates the marginal costs of emission reduction in the EU. The question whether EU policy passes the benefit-cost test is, at first sight, simply a matter of comparing the two estimates. However, there are complications. Firstly, EU policy is not cost-effective. The same target can be met at a much lower cost (Böhringer et al. 2009b). As cost-effectiveness is a condition for efficiency, this alone means that EU policy fails the benefit-cost test. I therefore compare the marginal damage costs of climate change (Table 1) to the marginal abatement costs for the *ideal* policy (Table 3, bottom row) rather than for the *actual* policy.

Secondly, both marginal costs and marginal benefits are rather uncertain. I therefore compute the probability that EU policy meets the benefit-cost test. I take the probability density function of the marginal damage costs of climate change from (Tol 2009a). Table 1 displays some of the characteristics. Note that, for this study, I converted the estimates of the social cost of carbon to 2007 Euro per tonne of carbon dioxide.

I derive the probability density function of the marginal abatement costs in the same manner as (Tol 2009a) derived the uncertainty about the social cost of carbon.

Each of the six estimates of the marginal abatement costs in Table 3 is assumed to be the central estimate of a Normal distribution.[7] The standard deviation of each of the six estimates is assumed to be equal to the standard deviation between the six estimates. The joint probability density is the rescaled sum of the individual probability densities.[8] See Figure 3.

As the probability densities of the marginal abatement costs and the marginal damages costs are mutually independent, the bivariate probability density is the outer product of the two. The chance of meeting the benefit-cost test is then the integral over the bivariate probability density under the condition that the marginal abatement costs is less than or equal to the marginal damage cost.

If all estimates of the marginal damage costs are used, there is a chance of 43% that the benefit-cost test is met (cf. Table 4). If only estimates with a zero percent pure rate of time preference are used, this chance increases to 60%. It falls to 26% for a one percent pure rate of time preference, and to 4.5% for a three percent pure rate of time preference. EU climate policy can be justified by great care for the future (i.e., a low discount rate) and by substantial aversion to risk (i.e., accepting a low probability of passing the benefit-cost test).

4.3. Total costs and benefits

Table 4 also shows the expected value of the benefits, which follows from the bivariate distribution of absolute abatement[9] (Figure 3) and social cost of carbon. The expected benefit varies between 7 and 102 billion euro, depending on the pure rate of time preference assumed (if any). The expected cost is 209 billion euro, 1.3% of projected GDP in 2020,[10] if emission abatement is implemented as planned. The benefit-cost ratio ranges between 0.03 and 0.49. If emission abatement is implemented in the cost-effective manner, expected costs fall to 116 billion euro, 0.7% of GDP. The benefit-cost ratio increases to between 0.06 and 0.88.

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[7] Unlike the impacts of climate change, there is no reason to believe that the uncertainty about the costs of emission reduction is asymmetric or fat-tailed.

[8] Vote-counting as used here, while not entirely appropriate, leads to a wider spread than using Bayes' rule.

[9] The distribution of absolute abatement is constructed as above: there are four best guesses, one each from the four models; the standard deviation of each best guess is assumed to be equal to the standard deviation between the best guesses; each individual estimate is assumed to be normally distributed; and the joint distribution is based on aggregating and rescaling the individual distributions.

[10] The models were all calibrated to the same scenario of economic and population growth.

At first sight, the benefit-cost ratios seem to be at odds with the estimated probabilities of meeting in the benefit-cost test, also displayed in Table 4. This illustrates the third problem with doing a benefit-cost analysis of a regional solution to a global problem. The results of the marginal/probability and total/expected cost analysis deviate from one another because the former implicitly assumes that the same carbon tax is applied outside the EU whereas the latter only considers the costs and benefits of emission reduction in Europe – that is, the benefits of emission reduction elsewhere are omitted. Equating the marginal costs of emission reduction to the marginal benefits would increase welfare – if the Pigou tax is applied to all emissions. However, only European emissions are regulated. Therefore, the benefits are only a fraction of the benefits of a global abatement policy – but the costs to Europe are the same.[11]

4.4. The optimal level of abatement

Cost-benefit analysis would recommend that level of emission abatement for which the expected marginal damage cost equals the expected marginal abatement cost.[12] The latter is difficult to ascertain as much of the variation between my six estimates of the marginal abatement costs is explained by differences in the no-additional-climate-policy scenarios used by the models. Therefore, I do the cost-benefit analysis separately for each model. I assume that the abatement cost curve is quadratic in emission reduction from baseline. The marginal abatement cost curve is therefore linear, and the "optimal" abatement level follows from rescaling the abatement level used by each model.

Table 5 shows the results. The EU target is to cut 2020 emissions to 20% below 1990 emissions. This implies a cut of 19% to 30% below baseline emissions, depending on the model. If the pure rate of time preference is 3% per year, the target falls to 1.4-2.5% from the base year (1990), which is 1.6-2.7% from the baseline. For a 1% pure rate of time preference, the optimal target is 6.9 to 12% from base year (7.6 to 13% from baseline). For a 0% pure rate of time preference, the optimal target exceeds the EU target: 22% to 38% from base year (24% to 42% from baseline). If all estimates of the social cost of carbon are considered regardless of the discount rate,

[11] In fact, costs are higher because of leakage (Bernard and Vielle 2009).

[12] Assuming, as above, that all emissions are regulated.

two models suggest that the EU target is too stringent and two models suggest that it is too lenient. The optimal target is 14% to 24% from base year (15% to 27% from baseline). As above, the EU emission reduction targets can be justified only with a low discount rate.

5. Discussion and conclusion

In this paper, I survey the marginal impacts of climate change and the (marginal) impacts of greenhouse gas emission reduction, particularly in the European Union. I then bring the two strands together in a cost-benefit analysis of the EU targets for 2020. The marginal costs of climate change are uncertain, with negative surprises more likely than positive surprises. Estimates also depend on ethical choices, such as the discount rate. A modest carbon tax can be easily justified. The current carbon price in the ETS is well within the range of available estimates. Emission reduction can be done cheaply, but this requires that emissions gradually deviate from the baseline scenario and that policy is well-designed and takes account of previous regulations. I find that planned EU policy does not meet these conditions. It is twice as expensive as needed, and would cost the equivalent of one in ten years of economic growth.

Comparing the orders of magnitude of the costs of emission reduction and the impacts of climate change suggests that the EU emissions targets for 2020 are not likely to meet the benefit-cost test. Indeed, for a standard discount rate, the benefit-cost ratio is rather poor (1/30). The EU targets become more attractive if policy implementation would be improved or if substantial weight would be placed on the remote future, but one would need a very low discount rate to justify the 20% emission reduction target for 2020.

As EU climate policy for 2020 cannot stand on its climate merits, could the targets be justified in another manner? There are separate targets for renewable energy, which would promote "energy security". Energy security is a fluid concept. Wind and solar power are less reliable than thermal power generation. Energy security may also be interpreted as diversification of supply. If so, promoting renewables is a second-best policy. Costs are unnecessarily high, and benefits have yet to be quantified (Roques et al. 2008). Energy security may also be interpreted as reducing the import of energy. Again, promoting renewables is a second-best policy, and costs are higher than need be. Benefits are unquantified – and may actually be negative as is usually the case with import substitution (Bruton 1998). More informally, politicians regularly argue that climate policy would stimulate economic growth, innovation, and employment. Raising the costs of an essential input to the economy is unlikely to accelerate economic growth (Weyant 1993). Climate policy would redirect innovation rather than enhance it (Smulders and Gradus 1996). While appropriate tax reform may stimulate job creation (Patuelli et al. 2005) , actual policies are different. It is therefore unlikely that the EU greenhouse gas emission reduction targets would pass the cost-benefit test even if the scope is widened.

Acknowledgements

All errors and opinions are mine.

Table 1. The mean and standard deviation of social cost of carbon (euro/tonne CO_2) for a Fisher-Tippett distribution fitted to 232 published estimates, and to three subsets of these estimates based on the pure rate of time preference.

	Fitted distribution (weighted)			
	All	Pure rate of time preference		
		0%	1%	3%
Mean	49	76	24	5
StDev	81	71	26	5
Mode	14	35	13	3
33%ile	10	35	10	2
Median	32	58	20	4
67%ile	59	93	32	7
90%ile	135	177	58	12
95%ile	185	206	72	15
99%ile	439	265	103	19

Table 2. The impact of the EU 20/20/2020 package on welfare (%) in 2020.

	Mean	StDev	PACE	DART	GEMINI-E3	WorldScan	PRIMES	PRIMES
Austria	-1.2	1.6	-0.8	-4.4	-0.5	-0.4	-0.6	-0.3
Belgium	0.1	2.9	-0.8	-2.5	5.8	-0.4	-0.9	-0.7
Bulgaria	-0.6	2.1	-0.8	-4.4	-0.5	-0.4	1.4	1.2
Cyprus	-1.2	2.1	-0.8	-5.5	-0.5	-0.4	-0.1	-0.1
Czech Rep	-0.8	1.8	-0.8	-4.4	-0.5	-0.4	0.5	0.5
Denmark	-1.2	1.9	-0.8	-5.2	-0.5	-0.4	-0.4	-0.1
Estonia	-0.8	1.8	-0.8	-4.4	-0.5	-0.4	0.5	0.5
Finland	-1.2	1.9	-0.8	-5.2	-0.5	-0.4	-0.3	-0.2
France	-1.5	1.5	-0.8	-4.0	-2.6	-0.4	-0.5	-0.5
Germany	-1.5	1.9	-0.8	-5.4	-1.0	-0.4	-0.7	-0.6
Greece	-1.4	2.0	-0.8	-5.5	-0.5	-0.4	-0.5	-0.6
Hungary	-0.9	1.8	-0.8	-4.4	-0.5	-0.4	0.2	0.4
Ireland	-1.2	1.6	-0.8	-4.4	-0.5	-0.4	-0.6	-0.5
Italy	-1.7	1.9	-0.8	-5.5	-1.9	-0.4	-1.1	-0.7
Latvia	-1.1	1.6	-0.8	-4.4	-0.5	-0.4	-0.6	0.0
Lithuania	-0.8	1.9	-0.8	-4.4	-0.5	-0.4	0.5	0.7
Luxembourg	-1.0	0.8	-0.8	-2.5	-0.5	-0.4	-1.0	-0.7
Malta	-1.2	2.2	-0.8	-5.5	-0.5	-0.4	0.2	0.0
Netherlands	0.2	2.7	-0.8	-2.5	5.3	-0.4	-0.5	-0.3
Poland	-1.4	1.8	-0.8	-4.4	-2.9	-0.4	-0.1	-0.1
Portugal	-1.4	2.0	-0.8	-5.5	-0.5	-0.4	-0.5	-0.5
Romania	-1.0	1.7	-0.8	-4.4	-0.5	-0.4	-0.1	-0.1
Slovakia	-1.1	1.6	-0.8	-4.4	-0.5	-0.4	-0.4	-0.3
Slovenia	-1.3	1.5	-0.8	-4.4	-0.5	-0.4	-1.0	-0.8
Spain	-1.7	2.0	-0.8	-5.5	-2.1	-0.4	-0.9	-0.4
Sweden	-1.4	1.9	-0.8	-5.2	-0.5	-0.4	-0.8	-0.8
UK	-1.4	1.5	-0.8	-3.7	-2.8	-0.4	-0.4	-0.4
EU	-1.3	1.6	-0.8	-4.5	-1.3	-0.4	-0.6	-0.5
First best	-0.7	0.6	-0.5	-2.0	-0.7	-0.3	-0.6	-0.5

Sources: PACE (Böhringer et al. 2009a), DART (Kretschmer et al. 2009), Gemini-E3 (Bernard and Vielle 2009), WorldScan (Boeters and Koornneef 2010), PRIMES (Capros et al. 2008); PRIMES appears twice as it published estimates based on an overly optimistic and an overly pessimistic interpretation of the rules on CDM.

Table 3. The cost of carbon (€/tCO_2) inside and outside the EU ETS in 2020.

	Mean	StDev	PACE	DART	GEMINI-E3	WorldScan	PRIMES	PRIMES
Austria	42	33	106	33	15	44	22	30
Belgium	175	281	106	103	743	44	22	30
Bulgaria	42	33	106	33	15	44	22	30
Cyprus	59	51	106	137	15	44	22	30
Czech Republic	42	33	106	33	15	44	22	30
Denmark	79	94	106	259	15	44	22	30
Estonia	42	33	106	33	15	44	22	30
Finland	79	94	106	259	15	44	22	30
France	120	128	106	158	357	44	22	30
Germany	72	48	106	83	145	44	22	30
Greece	59	51	106	137	15	44	22	30
Hungary	42	33	106	33	15	44	22	30
Ireland	42	33	106	33	15	44	22	30
Italy	63	48	106	137	35	44	22	30
Latvia	42	33	106	33	15	44	22	30
Lithuania	42	33	106	33	15	44	22	30
Luxembourg	53	41	106	103	15	44	22	30
Malta	59	51	106	137	15	44	22	30
Netherlands	116	139	106	103	389	44	22	30
Poland	39	36	106	33	0	44	22	30
Portugal	59	51	106	137	15	44	22	30
Romania	42	33	106	33	15	44	22	30
Slovakia	42	33	106	33	15	44	22	30
Slovenia	42	33	106	33	15	44	22	30
Spain	86	63	106	137	174	44	22	30
Sweden	79	94	106	259	15	44	22	30
United Kingdom	126	143	106	151	400	44	22	30
EU	75	52	106	95	155	44	22	30
ETS	32	22	15	35	71	7	30	30
First best	44	22	37	68	72	17	30	39

Sources: PACE (Böhringer et al. 2009a), DART (Kretschmer et al. 2009), Gemini-E3 (Bernard and Vielle 2009), WorldScan (Boeters and Koornneef 2010), PRIMES (Capros et al. 2008) ; PRIMES appears twice as it published estimates based on an overly optimistic and an overly pessimistic interpretation of the rules on CDM.

Table 4. Cost-benefit analysis of the EU 20/20/2020 package: Four alternative estimates of the social cost of carbon (cf. Table 2), the probability of the EU policy meeting the benefit-cost test, the expected value of the benefit, and the benefit-cost ratio for planned and cost-effective implementation of the EU policy.

	All	0%	1%	3%
Social cost of carbon (€/tCO_2)	49	76	24	5
Probability of EU policy meeting the benefit-cost test	43.1%	60.0%	26.1%	4.5%
Expected benefit (bln €)	66.1	102.2	39.1	7.1
Benefit-cost ratio (policy as proposed @ 209.3 bln €)	.32	.49	.15	.03
Benefit-cost ratio (cost-effective policy @ 115.8 bln €)	.57	.88	.28	.06

Table 5. *Proposed* (EU) and optimal (all, N%) emission reduction in 2020.

	Mean	StDev	PRIMES	PACE	DART	Gemini-E3
From base year (1990)						
EU	*20.0%*	-	*20.0%*	*20.0%*	*20.0%*	*20.0%*
All	20.7%	4.9%	24.4%	24.6%	19.6%	14.2%
0%	32.1%	7.6%	37.8%	38.2%	30.4%	22.0%
1%	10.1%	2.4%	11.9%	12.1%	9.6%	6.9%
3%	2.1%	0.5%	2.5%	2.5%	2.0%	1.4%
From base line (2020)						
EU	*22.9%*	*4.9%*	*18.8%*	*20.3%*	*29.9%*	*22.7%*
All	22.6%	5.4%	26.6%	26.9%	21.5%	15.5%
0%	35.1%	8.4%	41.3%	41.7%	33.3%	24.0%
1%	11.1%	2.6%	13.0%	13.2%	10.5%	7.6%
3%	2.3%	0.5%	2.7%	2.7%	2.2%	1.6%

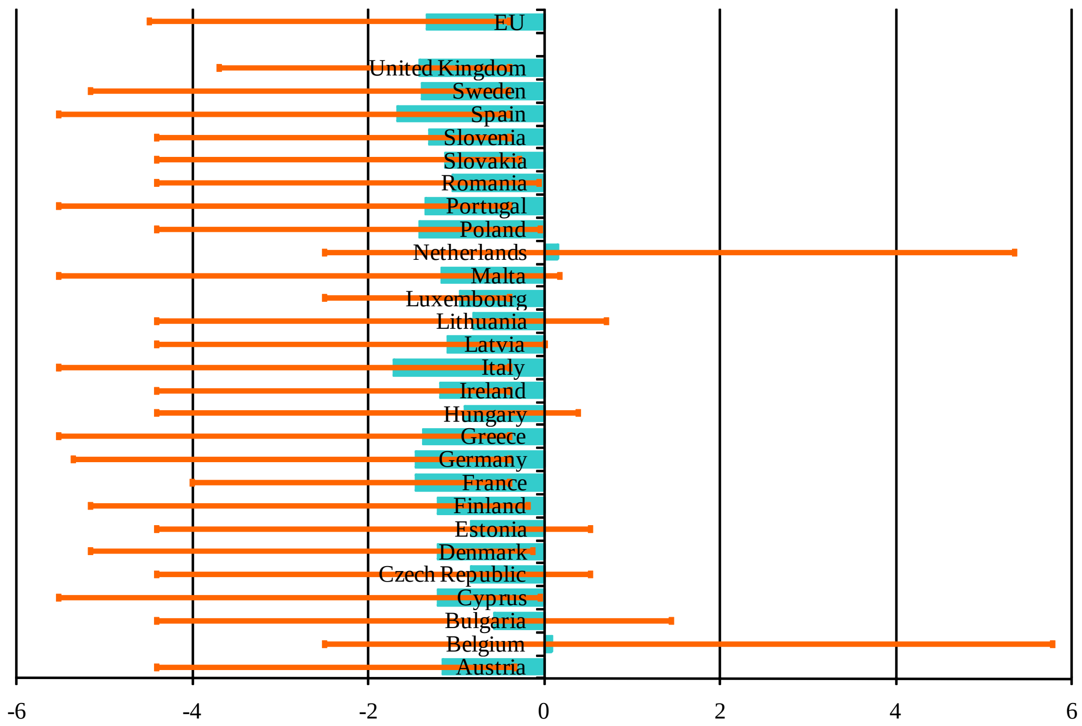

Figure 1. The 2020 welfare impact (percentage) of the EU 20/20/2020 package per Member State and for the EU as a whole; the bars show the average of six published estimates; the lines indicate the range of results.

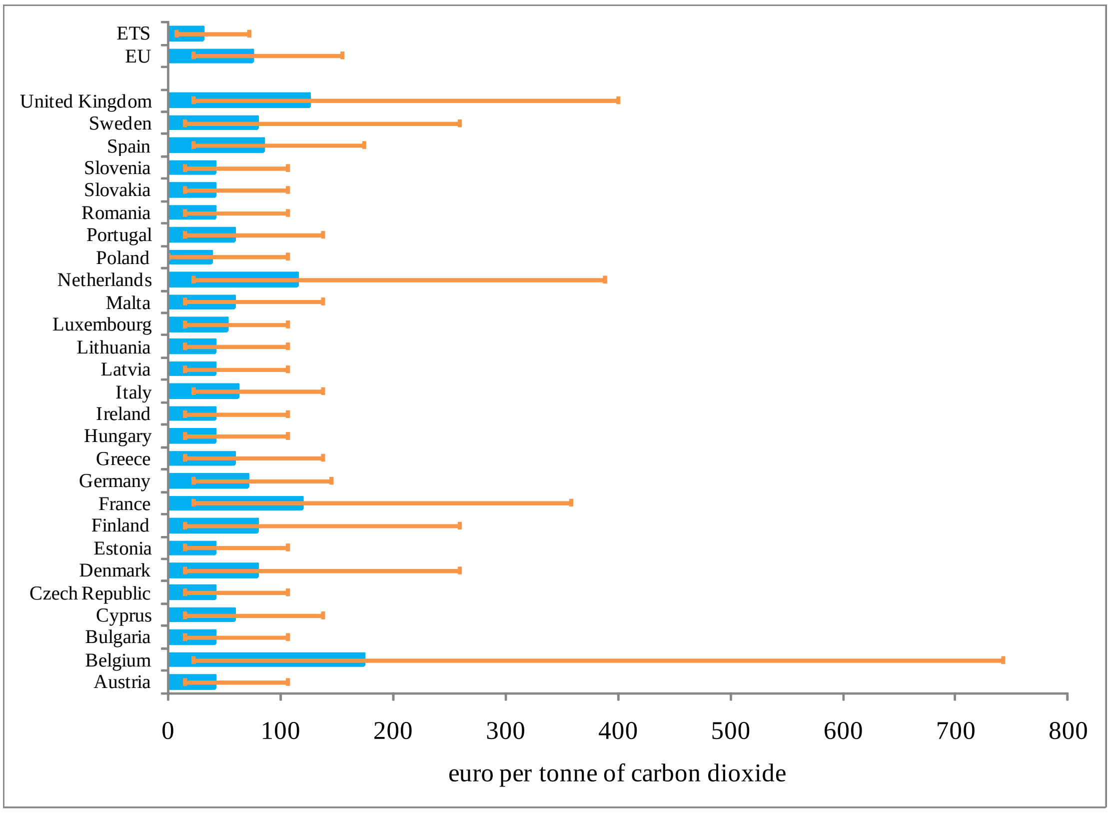

Figure 2. The 2020 price of carbon (2005 euro per tonne of carbon dioxide) for the EU 20/20/2020 package per Member State (non-ETS), for the EU one average (non-ETS) and for the Emissions Trading System (ETS); the bars show the average of six published estimates; the lines indicate the range of results.

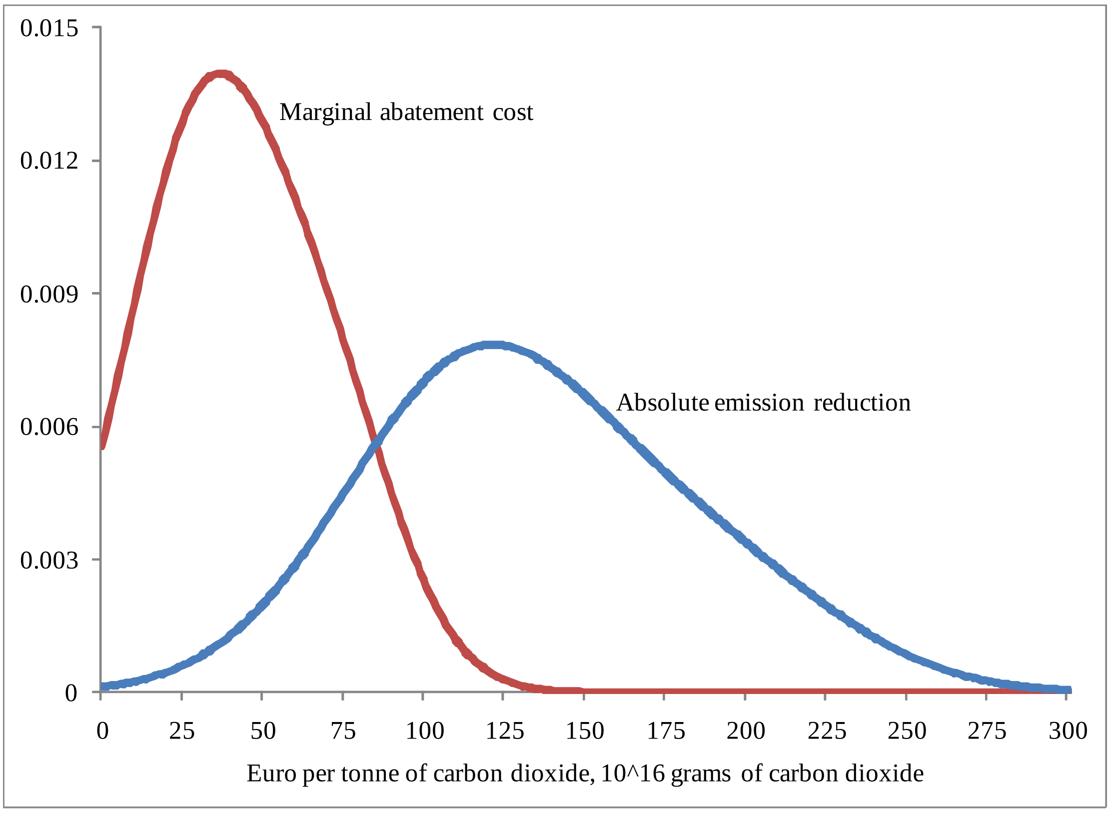

Figure 3. The probability density functions of the marginal abatement costs and the absolute emission reduction in the EU in 2020.

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